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Roy et al.

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(54) **PAUSE REQUEST PROCESSING FOR DATA TRAFFIC MODIFICATION**

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(51) **Int. Cl.**
G06F 13/38 (2006.01)

(52) **U.S. Cl.** **710/29**; 710/33; 710/54; 710/72

(58) **Field of Classification Search** ..... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,523,235	B2 *	4/2009	Nemazie et al.	710/74
2006/0267798	A1	11/2006	Jacobsen et al.	41/931
2007/0005838	A1 *	1/2007	Chang et al.	710/62
2007/0189176	A1 *	8/2007	Milne et al.	370/241
2007/0220357	A1 *	9/2007	Vedanabhatla et al.	714/43

OTHER PUBLICATIONS

"SAS Infusion Error Injection Platform for Serial Attached SCSI and Serial ATA," LeCroy Protocol Solutions Group, Believed to have been publicly available as of Dec. 21, 2004, 2 pages.

"SAS Infusion User Manual, Error Injection Platform for Serial Attached SCSI and Serial ATA," User Manual Version 1.21 for Software Version 1.2, LeCroy Protocol Solutions Group, Feb. 2007, 113 pages.

(Continued)

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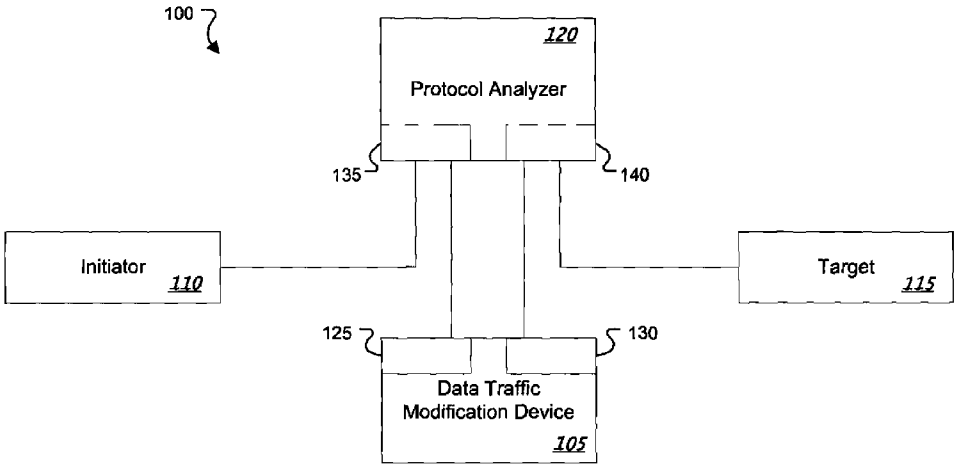
(74) *Attorney, Agent, or Firm* — Gordon Kessler

(57) **ABSTRACT**

Apparatus and associated systems and methods may relate to a data traffic modification system that may include a processing module to handle SATA-compliant data transfers in which a source device or a target device issues requests to pause and subsequently to resume the data transfer. In various implementations, a data traffic modification device may selectively modify data traffic upon the occurrence of a predetermined condition. In one illustrative example, if a target device for the data transfer issues a pause request (e.g., to prevent a buffer overflow), the data traffic modification device may generate a pause acknowledge signal to the target device within a response time specified by the protocol. In another illustrative example, if a source device for the data transfer issues a pause request, the data traffic modification device may generate a pause acknowledge signal to the source device within the response time specified by the protocol.

28 Claims, 10 Drawing Sheets



OTHER PUBLICATIONS

"SAS Infusion, SATA Infusion, FAQ," LeCroy Protocol Solutions Group, 2006, 3 pages.
"SAS Infusion and SATA Infusion Error Injector and Traffic Modifier," LeCroy Protocol Solutions Group, Believed to have been publicly available as of Mar. 29, 2005, 6 pages.
"Infusion 1.20—Release Notes," Updated Aug. 21, 2006, LeCroy Protocol Solutions Group, Aug. 21, 2006, 5 pages.
"Product Bulletin (#IF-001) SAS/SATA Infusion Announcement," LeCroy Protocol Solutions Group, Feb. 28, 2005, 2 pages.
"LeCroy Introduces Error Injection System For Serial Attached SCSI And Serial ATA," LeCroy Press Release, Mar. 1, 2005, 2 pages.
"Finisar Adds SAS and SATA Protocols to Its Industry-Leading Xgig(R) Analyzer 3.0," http://investor.finisar.com/ReleaseDetail.cfm?pf=yes&ReleaseID=186233, printed Feb. 7, 2007, Feb. 1, 2006, 2 pages.
"Finisar Announces Next Generation Analysis Solutions for Storage Area Networks (SANs)," http://investor.finisar.com/ReleaseDetail.cfm?pf=yes&ReleaseID=146677, printed Feb. 7, 2007, Oct. 27, 2004, 2 pages.
"Finisar Announces First Protocol Analyzer for Consumer Electronics Storage Interface," http://investor.finisar.com/releasedetail.cfm?ReleaseID=184656, Jan. 18, 2006, 3 pages.

* cited by examiner

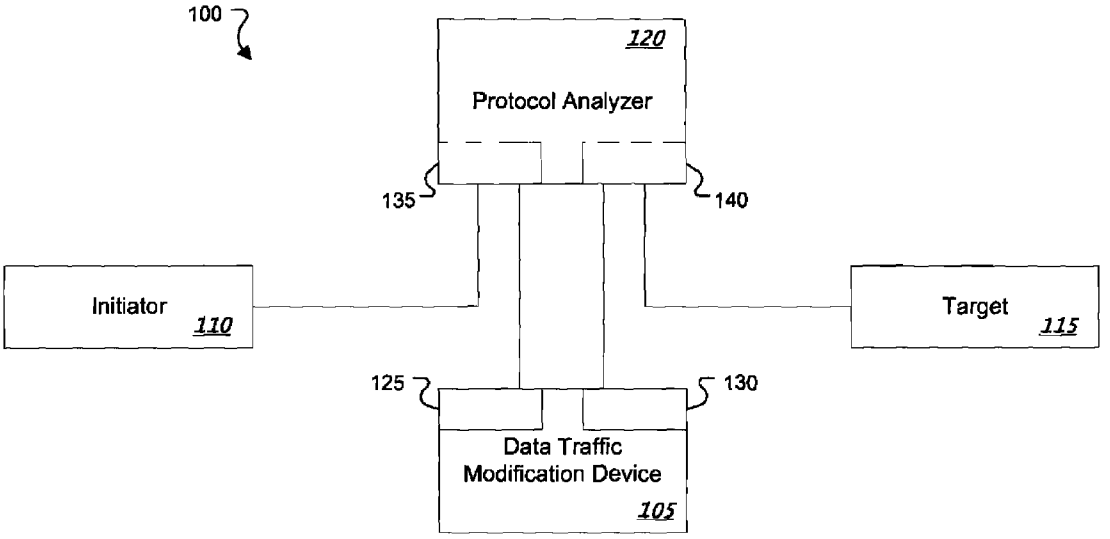

100
120
Protocol Analyzer
135
140
Initiator
110
Target
115
125
130
Data Traffic
Modification Device
105

FIG. 1

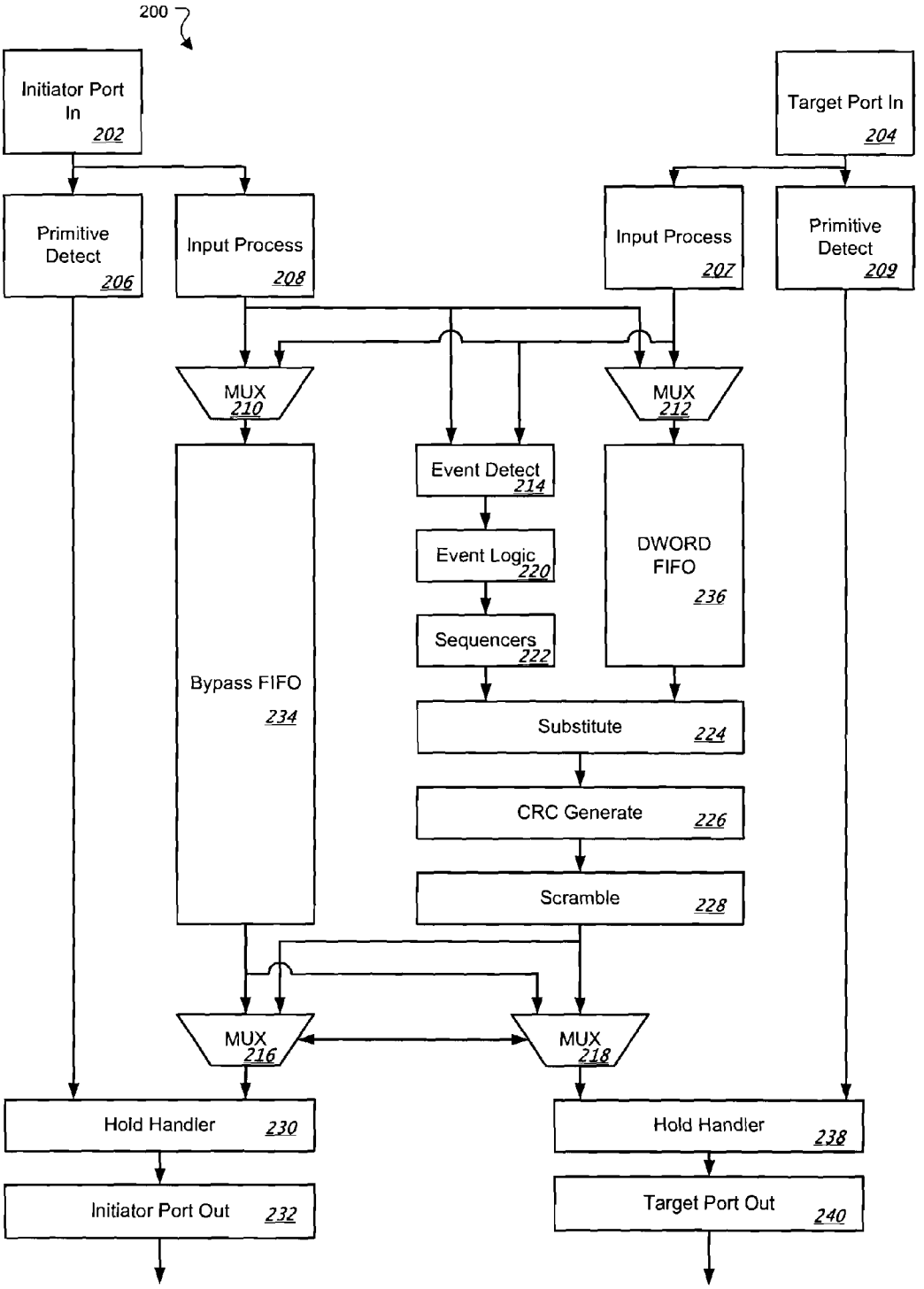

200
Initiator Port In 202
Target Port In 204
Primitive Detect 206
Input Process 208
Input Process 207
Primitive Detect 209
MUX 210
MUX 212
Event Detect 214
Event Logic 220
Sequencers 222
Bypass FIFO 234
DWORD FIFO 236
Substitute 224
CRC Generate 226
Scramble 228
MUX 216
MUX 218
Hold Handler 230
Hold Handler 238
Initiator Port Out 232
Target Port Out 240

FIG. 2

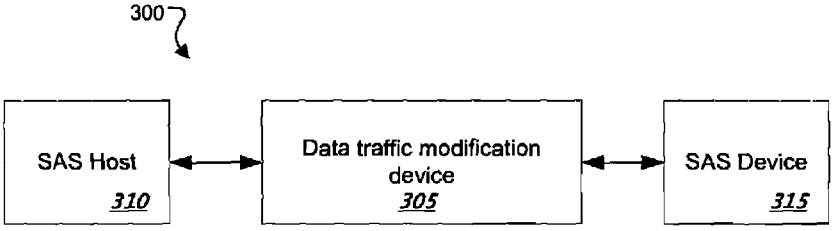


FIG. 3a

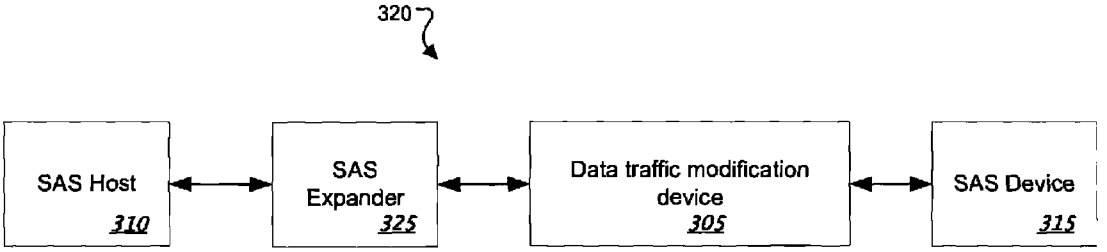


FIG. 3b

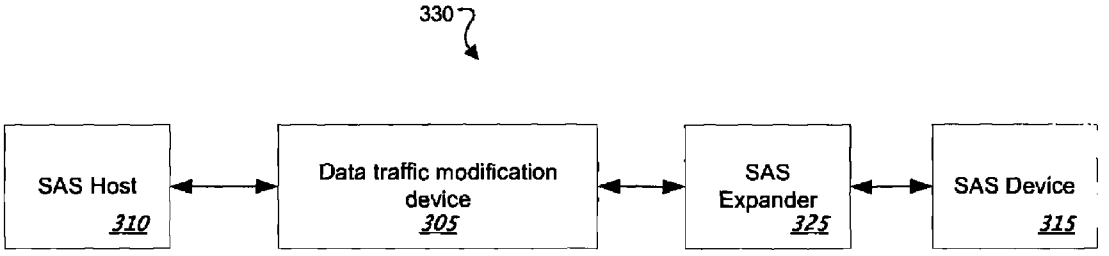


FIG. 3c

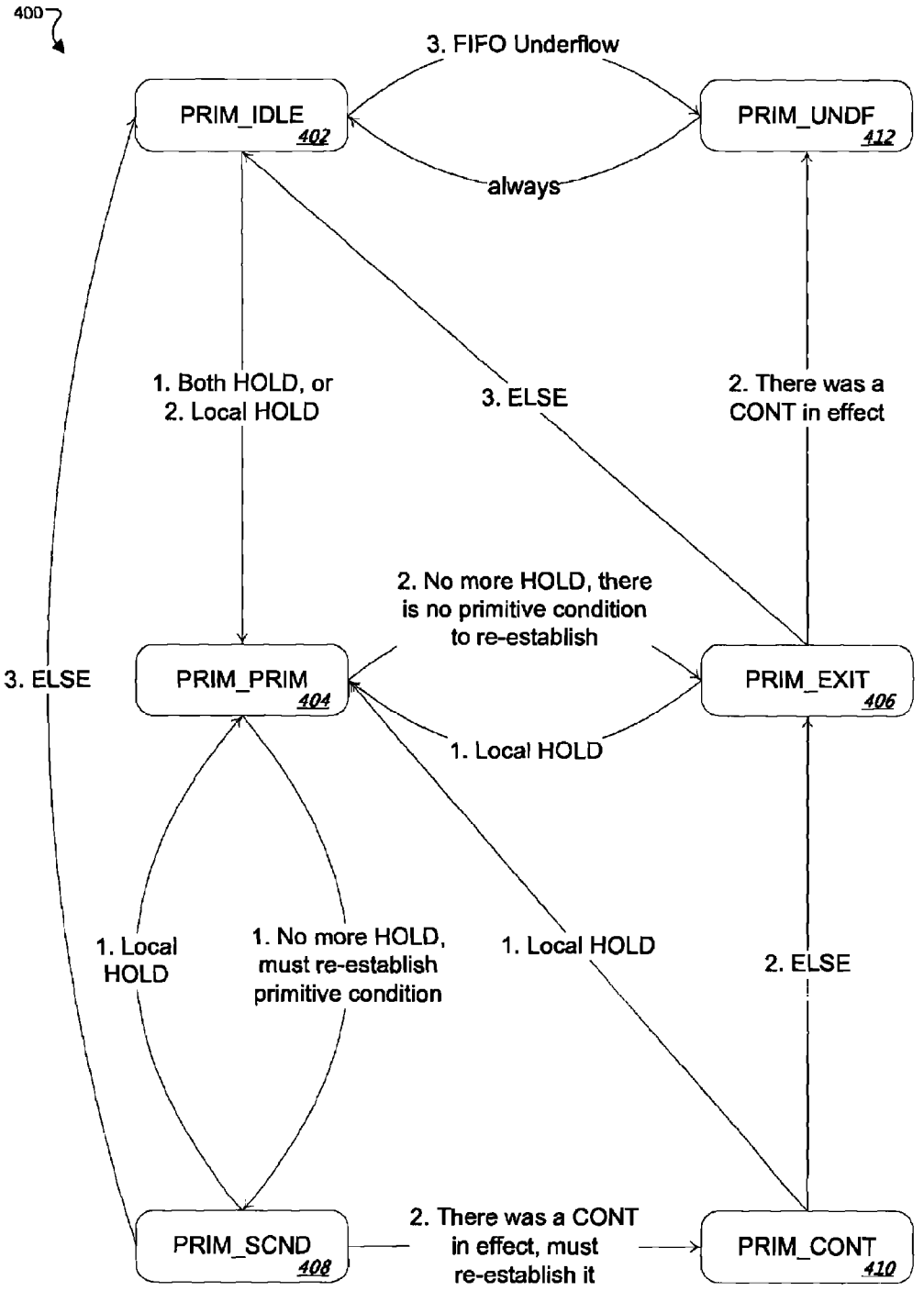

400
3. FIFO Underflow
PRIM_IDLE
402
PRIM_UNDF
412
always
1. Both HOLD, or
2. Local HOLD
3. ELSE
2. There was a
CONT in effect
2. No more HOLD, there
is no primitive condition
to re-establish
3. ELSE
PRIM_PRIM
404
PRIM_EXIT
406
1. Local HOLD
1. Local
HOLD
1. No more HOLD,
must re-establish
primitive condition
1. Local HOLD
2. ELSE
PRIM_SCND
408
2. There was a CONT
in effect, must
re-establish it
PRIM_CONT
410

FIG. 4

	510	520		530	540
		Sent by		Sent by	
		Infusion		Infusion	
	Sent by	Initiator		Target	Sent by
	Initiator	Port		Port	Target
1	Data A				R_IP
2	Data B				R_IP
3	Data C	R_IP		Data A	CONT
4	Data D	R_IP		Data B	XXX(R_IP)
5	Data E	CONT		Data C	XXX(R_IP)
6	Data F	XXX(R_IP)		Data D	XXX(R_IP)
7	Data G	XXX(R_IP)		Data E	HOLD
8	Data H	XXX(R_IP)		Data F	HOLD
9	Data I	HOLD		Data G	CONT
10	Data J	HOLD		Data H	XXX(HOLD)
11	Data K	CONT		HOLDA	XXX(HOLD)
12	Data L	XXX(HOLD)		HOLDA	XXX(HOLD)
13	HOLDA	XXX(HOLD)		HOLDA	XXX(HOLD)
14	HOLDA	XXX(HOLD)		HOLDA	XXX(HOLD)
15	CONT	XXX(HOLD)		HOLDA	XXX(HOLD)
16	XXX(HOLDA)	XXX(HOLD)		HOLDA	XXX(HOLD)
17	XXX(HOLDA)	XXX(HOLD)		HOLDA	XXX(HOLD)
18	XXX(HOLDA)	XXX(HOLD)		HOLDA	XXX(HOLD)
19	XXX(HOLDA)	XXX(HOLD)		HOLDA	R_IP
20	XXX(HOLDA)	XXX(HOLD)		HOLDA	R_IP
21	XXX(HOLDA)	R_IP		HOLDA	CONT
22	XXX(HOLDA)	R_IP		HOLDA	XXX(R_IP)
23	XXX(HOLDA)	CONT		Data I	XXX(R_IP)
24	XXX(HOLDA)	XXX(R_IP)		Data J	XXX(R_IP)
25	HOLDA	XXX(R_IP)		Data K	XXX(R_IP)
26	Data M	XXX(R_IP)		Data L	XXX(R_IP)
27	Data N	XXX(R_IP)		ALIGN(0)	XXX(R_IP)
28	Data O	XXX(R_IP)		ALIGN(0)	XXX(R_IP)
29				Data M	

FIG. 5

600

	610	620		630	640
		Sent by		Sent by	
		Infusion		Infusion	
	Sent by	Initiator		Target	Sent by
	Initiator	Port		Port	Target
1	Data A				R_IP
2	Data B				R_IP
3	Data C	R_IP		Data A	CONT
4	HOLD	R_IP		Data B	XXX(R_IP)
5	HOLD	CONT		Data C	XXX(R_IP)
6	CONT	XXX(R_IP)		HOLD	XXX(R_IP)
7	XXX(HOLD)	XXX(R_IP)		HOLD	XXX(R_IP)
8	XXX(HOLD)	HOLDA		CONT	XXX(R_IP)
9	XXX(HOLD)	HOLDA		XXX(HOLD)	XXX(R_IP)
10	XXX(HOLD)	HOLDA		XXX(HOLD)	HOLDA
11	XXX(HOLD)	HOLDA		XXX(HOLD)	HOLDA
12	HOLD	HOLDA		XXX(HOLD)	CONT
13	Data D	HOLDA		XXX(HOLD)	XXX(HOLDA)
14	Data E	HOLDA		HOLD	XXX(HOLDA)
15	Data F	HOLDA		Data D	XXX(HOLDA)
16	Data G	HOLDA		Data E	XXX(HOLDA)
17	Data H	R_IP		Data F	XXX(HOLDA)
18	Data I	R_IP		Data G	XXX(HOLDA)
19	Data J	CONT		Data H	R_IP
20	Data K	XXX(R_IP)		Data I	R_IP
21	Data L	XXX(R_IP)		Data J	CONT

FIG. 6

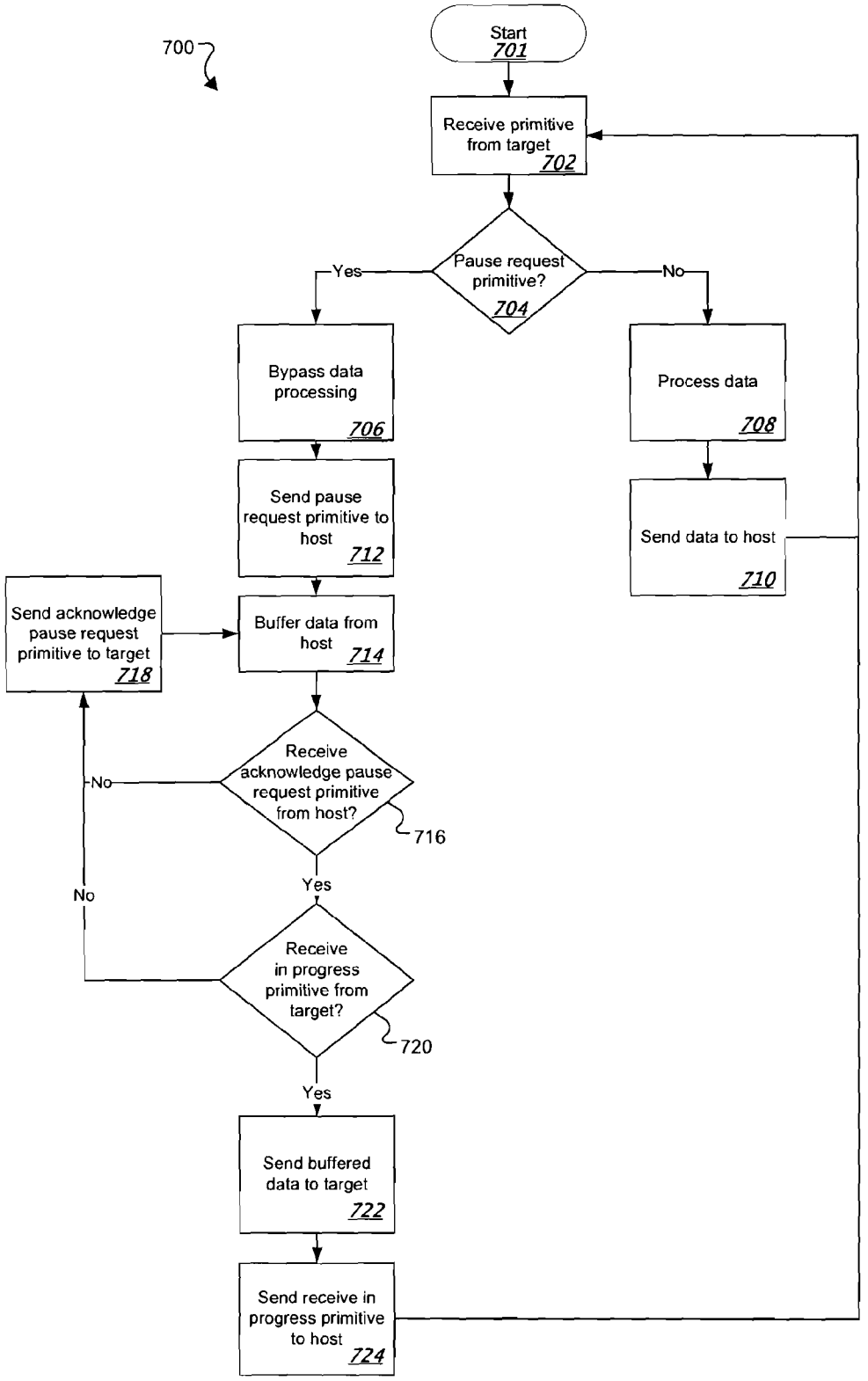

700
Start
701
Receive primitive from target
702
Pause request primitive?
704
Yes
No
Bypass data processing
706
Process data
708
Send pause request primitive to host
712
Send data to host
710
Send acknowledge pause request primitive to target
718
Buffer data from host
714
Receive acknowledge pause request primitive from host?
716
No
Yes
No
Receive in progress primitive from target?
720
Yes
Send buffered data to target
722
Send receive in progress primitive to host
724

FIG. 7

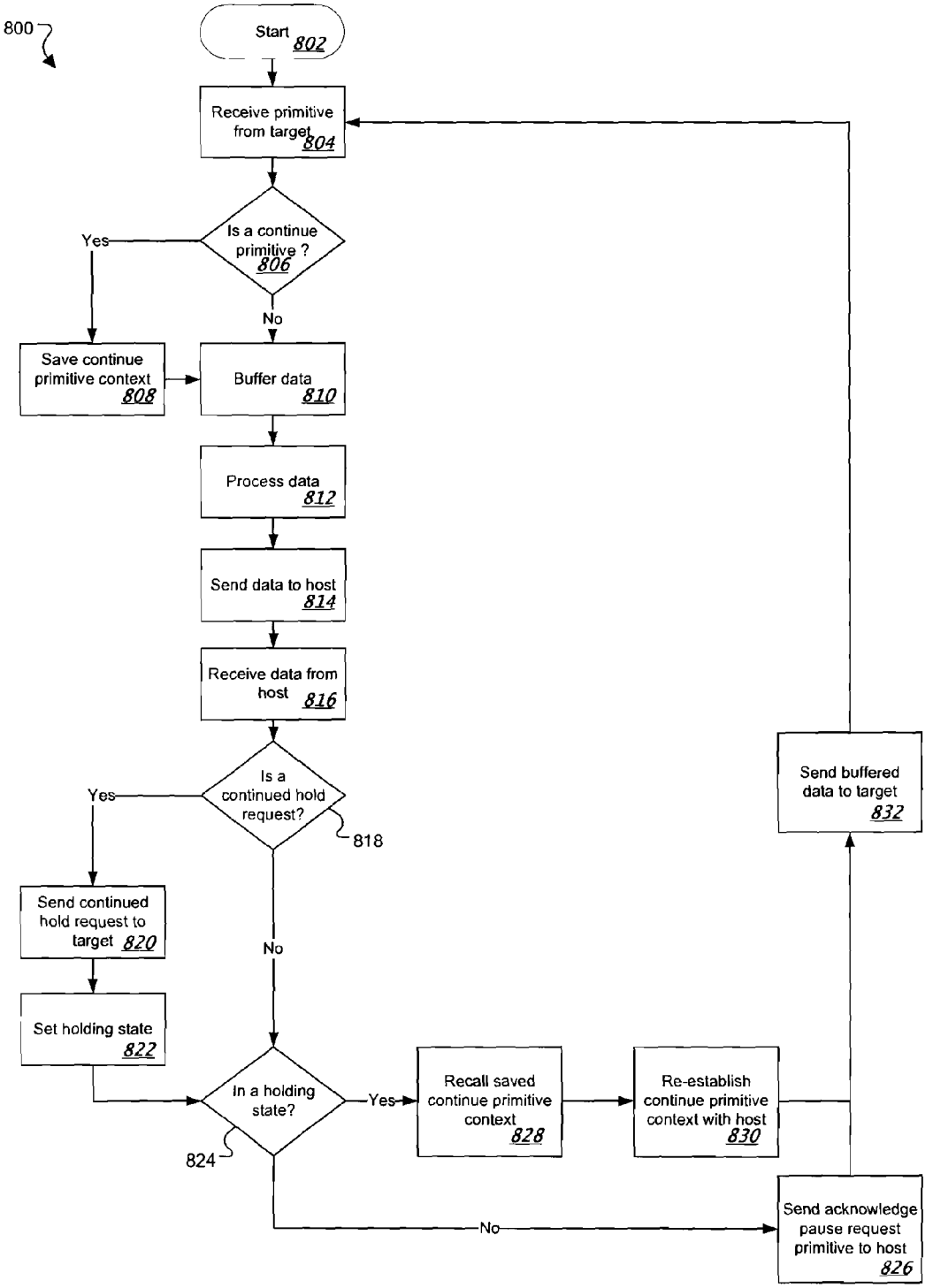

800
Start 802
Receive primitive from target 804
Is a continue primitive ? 806
Yes
No
Save continue primitive context 808
Buffer data 810
Process data 812
Send data to host 814
Receive data from host 816
Is a continued hold request? 818
Yes
No
Send continued hold request to target 820
Set holding state 822
In a holding state? 824
Yes
No
Recall saved continue primitive context 828
Re-establish continue primitive context with host 830
Send buffered data to target 832
Send acknowledge pause request primitive to host 826

FIG. 8

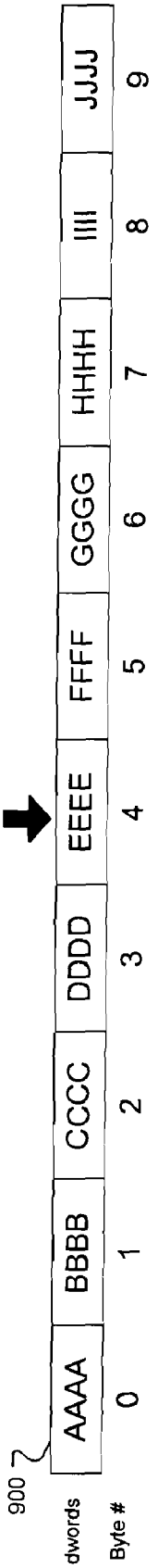


FIG. 9a

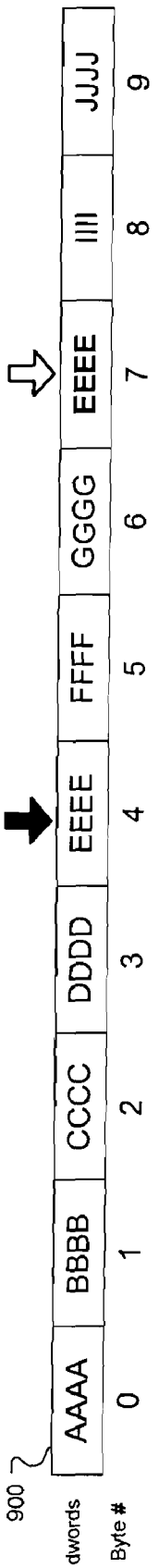


FIG. 9b

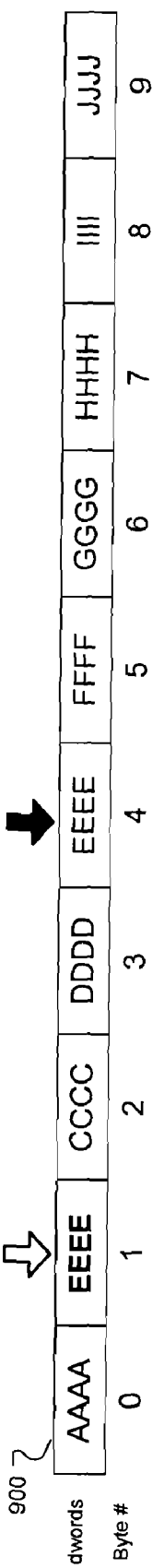


FIG. 9c

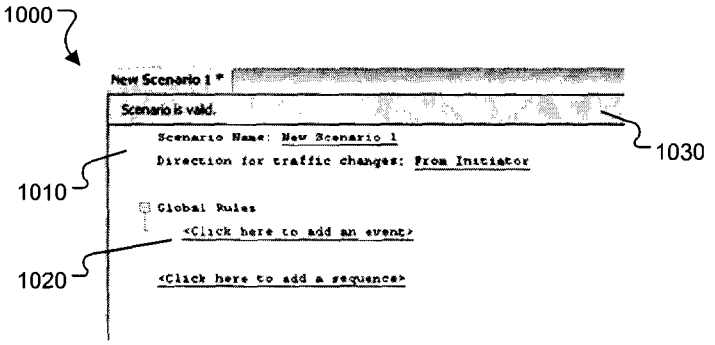


FIG. 10a

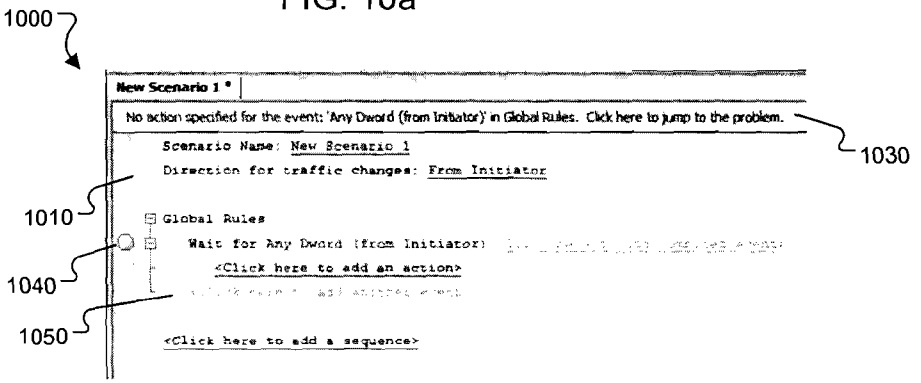


FIG. 10b

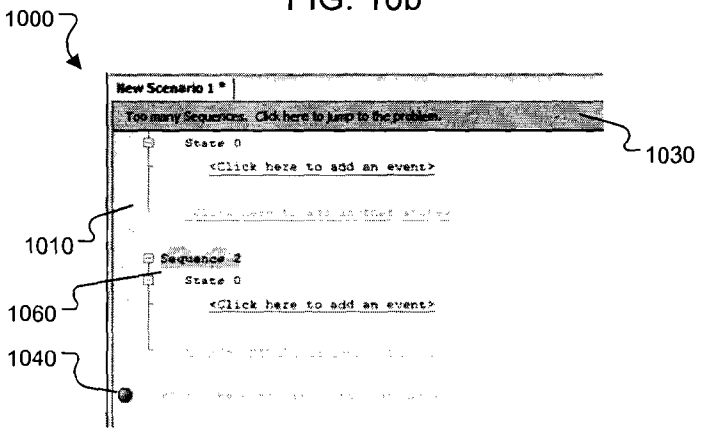


FIG. 10c

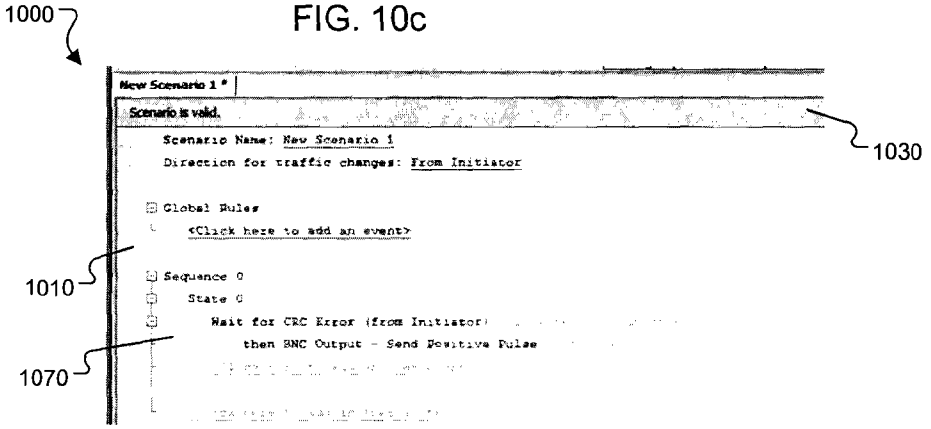


FIG. 10d

PAUSE REQUEST PROCESSING FOR DATA TRAFFIC MODIFICATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to: U.S. Patent Application Ser. No. 60/779,039, entitled "Data Capture Method And Apparatus," which was filed by Roy, A., et al. on Mar. 3, 2006; U.S. Patent Application Ser. No. 60/779,179, entitled "Protocol Traffic Modification Method And Apparatus," which was filed by Fouxman, E., et al. on Mar. 3, 2006; U.S. Patent Application Ser. No. 60/778,834, entitled "Cross Platform Trigger Method And Apparatus," which was filed by Roy, A., et al. on Mar. 3, 2006; U.S. Patent Application Ser. No. 60/779,084, entitled "Scenario View Method And Apparatus," which was filed by Lee, D., et al. on Mar. 3, 2006; U.S. Patent Application Ser. No. 60/779,180, entitled "Processing Of Hold Command In Protocol Analyzer," which was filed by Roy, A., et al. on Mar. 3, 2006; U.S. Patent Application Ser. No. 60/779,085, entitled "Communication Flow Recovery Method and Apparatus," which was filed by Karpov, D. on Mar. 3, 2006; and, U.S. provisional patent application 60/779,264 entitled, "Impairment and Monitoring Apparatus and Method," by Roy, A., et al., which was filed Mar. 3, 2006. This application also claims priority to U.S. Patent Application Ser. No. 60/892,093, entitled "Data Traffic Modifier Method and Apparatus," which was filed by Roy, A., et al. on Feb. 28, 2007. The disclosures of each of these priority documents are incorporated herein by reference.

TECHNICAL FIELD

Various embodiments relate to apparatus for modifying data traffic signals.

BACKGROUND

Data rates continue to increase in digital systems, communication systems, computer systems, and in other applications. In such applications, various devices communicate data using signals that may be encoded with information in the form of signal levels (e.g., amplitude) in certain intervals of time. Proper decoding of signals, for example, may involve measuring small signal levels in the correct time intervals. As data rates increase, margins of error for the signal level timing tend to decrease.

Likewise, operating frequencies for some analog signal processing systems continue to increase along with advances in telecommunication technologies, for example.

Various test and measurement equipment may be used to verify signal integrity in analog and digital systems. For example, oscilloscopes may be used to measure analog waveforms, and protocol analyzers may be used to monitor data in digitally formatted signals. Other waveform processing equipment may provide signal processing operations that may include, but are not limited to, acquisition (e.g., sampling, monitoring) and/or modification (e.g., filtering, time-shifting, amplification) of analog and/or digital signal waveforms.

In a typical data transfer, a data source device may transmit data to be received by a target device. Data transfers may be performed according to electrical and timing parameters specified by a communication protocol. Representative examples of well-known serial communication protocols include Fibre Channel, SATA (Serial Advanced Technology Attachment), SAS (serial attached SCSI (small computer system interface)), and SATA Tunneling Protocol (STP). Communication errors can occur when data transfers do not meet the protocol specifications.

SUMMARY

Apparatus and associated systems and methods may relate to a data traffic modification system that may include a processing module to handle SATA-compliant data transfers in which a source device or a target device issues requests to pause and subsequently to resume the data transfer. In various implementations, a data traffic modification device may selectively modify data traffic upon the occurrence of a predetermined condition. In one illustrative example, if a target device for the data transfer issues a pause request (e.g., to prevent a buffer overflow), the data traffic modification device may generate a pause acknowledge signal to the target device within a response time specified by the protocol. In another illustrative example, if a source device for the data transfer issues a pause request, the data traffic modification device may generate a pause acknowledge signal to the source device within the response time specified by the protocol.

Certain embodiments may provide one or more advantages. For example, a data traffic modification system may smoothly and robustly handle high speed data transfers between a wide variety of source and target devices. In various implementations, the data traffic modification device may overcome the delay associated with buffering the data transfer by monitoring bidirectional data traffic for pause requests, and responding rapidly by generating expected acknowledge signals within the response time expected by the device that issued the pause request. In some particular embodiments, a device capable of in-line data traffic modification device may respond to pause request signals within a response time (e.g., 20 double words) as specified by various protocols (e.g., SAS, STP, SATA, SATA 2.0, and the like). In one example, before resuming a data transfer after being paused by, for example, a source device, a data traffic modification device may advantageously restore a context in effect when the data transfer was paused. In another example, after generating an acknowledge signal in response to a pause request from a target device, the data traffic modification device may advantageously buffer data from the source device until the pause request propagates to the source device, and the source device pauses the data transfer in response to the pause request.

The details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. **1** illustrates a block diagram of an exemplary configuration capable of modifying data traffic.

FIG. **2** is a block diagram of an exemplary data traffic modification device.

FIGS. **3***a-c* are block diagrams depicting exemplary configurations for using a data traffic modification device.

FIG. **4** is a flow diagram of an exemplary state machine for data traffic modification.

FIG. **5** is a table that illustrates an exemplary communication session among a SATA initiator, a data traffic modification device, and a SATA target, when the SATA target requests a hold.

FIG. **6** is a table that that illustrates an exemplary communication session among a SATA initiator, a data traffic modification device, and a SATA target, when the SATA initiator requests a hold.

FIG. **7** is a block diagram depicting an exemplary method for processing a pause request from a SATA target coupled to a data traffic modification device.

FIG. **8** is a block diagram depicting an exemplary process for handling a context using in a data traffic modification device.

FIGS. **9***a-c* illustrate two exemplary data substitution processes being performed upon the data stream.

FIGS. **10***a-d* illustrate an exemplary graphical user interface for viewing and editing data modification scenarios.

DETAILED DESCRIPTION

FIG. **1** illustrates a block diagram **100** of an exemplary configuration for using a data traffic modification device **105**. The data traffic modification device **105** may be used to selectively modify some or all data traffic flowing between a SATA (Serial Advanced Technology Attachment) initiator **110**, such as a computer with a SATA interface, and a SATA target **115**, such as a hard disk drive or drive array. In some embodiments, the selective modification of data may be performed on data traffic in one or more directions. In some embodiments, the data may be modified to purposely alter the communications between the SATA initiator **110** and the SATA target **115**.

In the depicted example, the configuration **100** includes the data traffic modification device **105**, the initiator **110**, the target **115**, and a protocol analyzer **120**. The data traffic modification device includes a first port **125** and a second port **130**. In this example, the ports **125**, **130** are compliant with the SATA standard, and include two pairs of conductors in order to allow for bidirectional communications. The first port **125** is in communication with a first channel **135** of the protocol analyzer **120**, and the second port **130** is in communication with a second channel **140** of the protocol analyzer **120**. The first port **135** is also in communication with the initiator **10**, and the second port **140** is also in communication with the target **115**.

In the configuration **100**, communications between the SATA initiator **110** and the SATA target **115** may be modified by the data traffic modification device **105** and traced by the protocol analyzer **120**. This configuration may allow a technician to confirm that the data traffic modification device **105** has been configured correctly, or may allow a technician to observe how the SATA initiator **110** or SATA target **115** respond when either receives modified data.

While the exemplary configuration **100** has been described in terms of communications according to a version of SATA standard, various embodiments may use various versions of the SATA protocol (e.g., SATA 2.0), and/or protocols other than SATA. In some examples, the configuration **100** may use a SATA-compliant protocol such as SAS (serial attached SCSI (small computer system interface)) and/or SATA Tunneling Protocol (STP). In some embodiments, the data traffic modification device **105** may also be capable of using a combination of protocols. For example, the configuration **100** may be implemented with the SAS initiator **10** using SAS and the target **115** using SAS, STP, or SATA. In some further examples, a hub may be included to provide connections between at least one initiator **110** and at least one target **15**, where each connection may use a combination of protocols. Further aspects and examples relating to data traffic modification are described in U.S. provisional patent application 60/779,264 entitled, "Impairment and Monitoring Apparatus and Method," by Roy, A., et al., which was filed Mar. 3, 2006, and the contents of which are incorporated herein by reference.

FIG. **2** is a block diagram **200** depicting an exemplary data flow through the data traffic modification device **105** of FIG. **1**. Communications data may enter the data traffic modification device **105** through an initiator port in **202**, or through a target port in **204**. Data entering though the initiator port in **202** then passes to a first primitive detect module **206** and a first input processing module **208**. In some embodiments, the primitive detect module **206** may be configured to react to (or "snoop for") selected SATA primitives such as "HOLD." Data entering the block diagram **200** through the target port in **204** passes through a second input processing module **207** and a second primitive detect module **209**.

Data passing through the input processing module **208** is then passed to a first multiplexer **210**, a second multiplexer **212**, and an event detection module **214**. The first multiplexer **210** and second multiplexer **212** (as well as a third multiplexer **216** and a fourth multiplexer **218**) are present to control the paths through which each direction of data traffic should propagate through the block diagram **200**. In the depicted example, both directions of data traffic are monitored, but only one direction of data traffic can be selectively modified at any one time. The direction of data traffic to be selectively modified is routed by the multiplexers to a dword FIFO **236**, while the opposite direction of data traffic is routed through a bypass FIFO **234**.

In some other embodiments, more than one direction, lane or channel of data traffic may be modified at any one time. For example, multiplexers may be removed and/or additional hardware and corresponding software, examples of which are described below with reference to FIG. **2**, may be added to permit selective modification of data traffic in both directions of a bidirectional communication link, for example.

In FIG. **2**, data passing through the second multiplexer **212** flows through the dword buffer **236**. In some embodiments, the dword buffer **236** may be monitored by an event detect module **214**, an event logic module **220**, and/or a sequencer module **22'**, which couples to a substitution module **224**.

Data from either or both of the input process modules **207**, **208** may be received as inputs to the event detection module **214**, which may be configured (e.g., programmed) to identify selected primitives, out-of-band (OOB) messages, and the like. The event detection module **214** may be configured, for example, to identify user-Specified input conditions, the occurrence of which may cause a processor to perform operations to selectively modify the data stream, for example. Signals from the event detection module **214** are received by the event logic module **220**, which can be programmed by the user to provide a specified response to certain specified trigger conditions (e.g., primitives and data patterns detected in the event logic module **220**). These responses may include actions that selectively modify data in the data stream, drop data, sound an audible beep, stimulate a trigger port, or perform a combination of these or other actions.

From the event logic module **220**, control passes to a sequencer module **222**. The sequencer module **222** may be implemented as a user-programmable state machine. The sequencer module **222** state machine may be configured to cooperate with the event logic module **220** to modify (e.g., add to, ignore, remove, and/or replace some or all of the bits in a frame of data) the data stream. The data is then sent to a substitution module **224**. The substitution module **224** may cooperate with the sequencer module **222** to selectively modify one or more bits within a data frame, for example, based on operation of the state machine. Such substitutions may be performed, for example, in order to inject an error to test the response of the initiator **110** and/or the target **115**.

In some implementations, the data traffic may have data frames that include CRC (cyclical redundancy check) data, which may be used to verify the integrity of the data that is received. When the substitution module **224** modifies data in the data frame, the CRC for that frame may be incorrect for the modified data frame. A CRC generation module **226** may, for example, recalculate valid CRC data for the frame, and substitute this recalculated CRC data for the original CRC data in the data frame. Examples of processes for data substitution in a data traffic modification device are described in further detail in U.S. provisional patent application 60/779,039 entitled, "Data Capture Method and Apparatus," by Roy, A., et al., which was filed Mar. 3, 2006, and the contents of which are incorporated herein by reference. Control then passes to a scrambler module **228**. The scrambler module **228** may reduce the transmission of long repetitive data patterns that could contribute to electromagnetic interference.

Data leaving the scrambler module **228** is then passed to the third multiplexer **216** and the fourth multiplexer **218**. Data passed to the third multiplexer **216** may pass the data to the fourth multiplexer **218**, or vice versa, or the data may be passed to a first hold handler **230** or a second hold handler **238**. Data passed to the first hold handler **230** is sent to the initiator via an initiator port out **232**. Data passed to the second hold handler **238** is sent to the target via a target port out **240**.

In operation, the exemplary block diagram **200** illustrates a data traffic modification device configured to substantially reduce the propagation times that add delay to the acknowledgment of a pause request from either an initiator or a target device. Data propagating through the data modification path (modules **214**, **220-228**, **236**) may experience a delay caused by the previously described processing steps. Some communication protocols, such as the SATA specification, for example, specify that a transmitting device must, within a specified response time such as 20 dwords (double words, or 32-bit values), acknowledge a pause request signal by suspending the transmission of valid data and by sending a hold acknowledgement signal to acknowledge the pause request. The pause request may be to prompt the initiator to suspend the data transfer to avoid, for example, a buffer overflow, which may result in a loss of data or other problems. The data paths for propagating the pause request through the data traffic modification device (e.g., from the target port in **204** to the initiator port out **232**) include a buffer or memory. In the depicted example, and depending on the states of the multiplexers **210**, **212**, the data path through which a pause request would propagate includes either the bypass FIFO **234** or the dword FIFO **236**. The FIFOs **234**, **236** may be, for example, buffers FIFO (first in-first out), FILO (first in-last out), circular, linear, parallel, or combinations of these or other types of buffers. In some embodiments, the FIFOs **234**, **236** may be implemented using pointers to memory locations, one or more data stores, shift registers, or a combination of these or other buffering techniques.

In operation of the example block diagram **200**, the data traffic modification device may introduce a delay in the data stream. In some examples, such delay may substantially prevent the device requesting a pause from receiving a pause acknowledgment signal within response time specification for the protocol being used. Various embodiments may be adapted to meet a protocol's response time specification.

In an illustrative example, a target device (e.g., disk drive) may issue a pause request to an initiator (e.g., host or server) that is transferring data to the target device. The target may issue a pause request, for example, if it is receiving data faster that it can process the data. In the depicted figure, the primitive detect module **209** is configured to detect and react to pause requests from the target. In operation, the primitive detect module **209** may react by signaling the hold handler **238** to generate a pause request acknowledge signal back to the target. This process may allow a pause acknowledgement signal to be sent to the target while avoiding the delay associated with propagating through the buffer FIFOs **234**, **236**. In this example, data being transferred from the initiator may continue to be sent until the initiator receives and responds to the pause request after the pause request propagates through one of the FIFOs **234**, **236**. During this time, the valid data sent by the initiator may be buffered in one of the FIFOs **234**, **236** at least until the target breaks the pause state and the data transfer resumes.

In another illustrative example, an initiator (e.g., host device) may issue a pause request. After the pause request is issued, some time may pass while the pause request propagates though the block diagram **200** (e.g., from the initiator port in **202**, to the first input processing module **208**, through one of the FIFOs **234**, **236**, and to the target port out **240**). As such, the target may acknowledge the pause request after some delay that, in some examples, may exceed the response time specification for the communication protocol. After the initiator issues the pause request, the first primitive detect module **206** may detect the pause request and pass control to the first hold handler module **230**. The first hold handler module **230** then generates a pause acknowledgement message that is sent out the initiator port out **232**. When the initiator breaks the pause state, the substitution module **224** may generate signals to restore the context of the data stream that was in effect when the pause request was received. Examples of restoring the context upon resuming the data transfer are described in further detail with reference to FIG. **4**.

In some embodiments, such as those that use a version of the SATA protocol, the pause request may include, for example, a SATA HOLD primitive, the acknowledge pause request may include a SATA HOLDA primitive, and the continue primitive may include a SATA CONT primitive. Some protocols may specify certain rules associated with such primitives. For example, some protocols may impose a response specification that a pause request, for example, be acknowledged within a certain time period or that only a limited quantity of data in the data stream be transferred after a pause request is issued. Examples of processing pause primitives in a data traffic modification device are described in further detail in U.S. provisional patent application 60/779,180 entitled, "Processing Of Hold Command In Protocol Analyzer," by Roy, A., et al., which was filed Mar. 3, 2006, and the contents of which are incorporated herein by reference.

In some implementations, the traffic modification device **105** may generate pause request acknowledgement signals to satisfy the response time specified by the applicable protocols. Exemplary implementations for processing pause requests in the configuration **100** are described with reference to FIGS. **4-8**.

FIGS. **3***a-c* illustrate exemplary block diagrams depicting various configurations for using a data traffic modification device. FIG. **3***a* illustrates an exemplary block diagram **300** of an embodiment for the use of a data traffic modification device **305**. In this embodiment, the data traffic modification device **305** is placed between a SAS host **310** and a SAS device **315**. In some embodiments, the SAS device **315** may be replaced by a SATA device. In some embodiments, the SAS host **310** may be a SATA host if the configuration also includes a SATA device.

FIG. **3***b* illustrates and exemplary block diagram **320** of another embodiment for the use of the data traffic modification device **305**. In this embodiment, the SATA host **310** is connected to a SAS expander **325**. The SAS expander **325** is also connected to the data traffic modification device **305**, and the data traffic modification device **305** is connected to the SAS device **315**.

FIG. **3***c* illustrates an exemplary block diagram **330** of another implementation of the data traffic modification device **305**. In this example, the SAS host **310** is connected to the data traffic modification device **305**, the data traffic modification device **305** is connected to the SAS expander **325**, and the SAS expander **325** is connected to the SAS device **315**.

FIG. **4** illustrates a flow diagram of an exemplary state machine **400** used in a data traffic modifier. In one example, a SATA host may be sending data to a SATA target when the SATA target sends a pause request (as will be further described with reference to FIG. **5** and FIG. **7**). The state machine **400** starts in a PRIM_IDLE state **402**. During this state, the data traffic modification device propagates data between the host and the target. In the depicted example, the host is sending data to the target. If the data traffic modification device detects that the target has sent a pause request (e.g., a "HOLD" primitive), the state machine **400** responds by propagating the pause request to the host and transitioning to a PRIM_PRIM state **404**. During the PRIM_PRIM state **404**, the data traffic modification device generates a series of hold acknowledgements (e.g., a series of "HOLDA" primitives) and sends them to the target, and buffers any data that the host sends until the host acknowledges the pause request. When the target is once again able to receive data, the target may send a receiving message (e.g., a "R_IP" primitive, or a R_IP-R_IP-CONT sequence). When the data traffic modification device senses such a receiving message, and there is no continued state to re-establish, the state machine **400** propagates the receiving message to the host and transitions to a PRIM_EXIT state **406**. During the PRIM_EXIT state **406**, the data traffic modification device sends any data that may have been buffered. When the buffer has been emptied, the state machine **400** transitions back to the PRIM_IDLE state **402**.

In another example, the SATA host may send a pause request after sending one or more primitives. In this case the state machine **400** starts in the PRIM_IDLE state **402**. During the PRIM_IDLE state the data traffic modification device may receive a continued primitive message (e.g., a "R_IP-R_IP-CONT" sequence) from the target. The data traffic modification device may also receive a continued pause request from the host (e.g., a "HOLD-HOLD-CONT" sequence). Upon detection of the continued pause request, the state machine **400** propagates the continued pause request to the target, stores the context of the continued primitive message from the target, and then transitions to the PRIM_PRIM state. While in the PRIM_PRIM state, the data traffic modification device generates a series of hold acknowledgement messages and sends them to the host. The host may then send a single pause request to break the continued pause request and to resume propagating the data stream. In some embodiments, the SATA primitives that may be used to break a continued state may include, but are not limited to, HOLD, HOLDA, PMREQP, PMREQS, RERR, R_IP, R_OK, R_RDY, SYNC, WTRM, or XRDY. The state machine **400** responds by propagating the message to the target and transitioning to a PRIM_SCND state **408**. During the PRIM_SCND state **408**, the data traffic modification device recalls the stored context information and uses that stored context information to reestablish the continued target context that was in place prior to the arrival of the continued pause request from the host. Once the prior target context is reestablished, the state machine **400** transitions back to the PRIM_IDLE state **402**.

In another example, the SATA host may send a pause request after sending data to the target (as will be further illustrated by FIG. **6** and FIG. **8**). In this case, the state machine **400** starts in the PRIM_IDLE state **402** where the data traffic modification device propagates data between the host and target. During this state, the target sends a continued receiving message (e.g., a "R_IP-R_IP-CONT" sequence) and the host sends data. If the data traffic modification device detects that the host has sent a continued pause request, the data traffic modification device propagates that continued pause request to the target, stores the current context information, and transitions to the PRIM_PRIM state **404**. During the PRIM_PRIM state **404**, the data traffic modification device generates and sends a series of hold acknowledgement messages to the host. If the data traffic modification device then detects that the host has sent a command primitive to break the continued pause request, the state machine **400** propagates the primitive to the target, and transitions to the PRIM_SCND state **408**. During the PRIM_SCND state, the data traffic modification device recalls the previously stored target context information, and uses that information to reestablish the previous context. Since the previous context was a continued command, the state machine **400** transitions to a PRIM_CONT state **410**. During the PRIM_CONT state **410**, the data traffic modification device sends a continuation request to the target to reestablish the "continued" characteristic of the previous target context. The state machine **400** then transitions to the PRIM_EXIT state **406** to send any buffered data that may be in the data traffic modification device, and then returns to the PRIM_IDLE state **402**.

In some embodiments, the series of hold acknowledgement statements sent during the PRIM_PRIM state may be replaced by a continued hold acknowledgement message sequence, followed by a series of scrambled "keep alive" messages (e.g., a HOLDA-HOLDA-CONT-XXX(HOLDA)-XXX(HOLDA) . . . sequence).

FIG. **5** illustrates a table **500** that that depicts an exemplary communications session among a SATA initiator (shown in column **510**), a data traffic modification device, a data traffic modification device's initiator port (shown in a column **520**), a data traffic modification device's target port (shown in a column **530**), and a SATA target (shown in a column **540**). It should be noted that this table does not represent any particular time scale, and is intended to be only a general depiction of one possible flow of communications. In this example, the initiator is sending data in cycles **1-3**. It can also be seen that the target is sending a R_IP-R_IP-CONT sequence in cycles **1-3** to indicate that the target is receiving data. At cycles **3-5**, it can be seen that the R_IP sequence sent by the target has been relayed to the initiator port after some delay. Likewise, at cycle **7** the target sends a pause request as part of a HOLD-HOLD-CONT sequence, and after a similar delay the HOLD-HOLD-CONT sequence is relayed at the initiator port. Due to the normal delay required for the initiator to respond to a pause request, in addition to the delay introduced by the data traffic modification device, the initiator does not respond to the pause request until cycle **13**, when it sends a hold acknowledgement primitive. In some instances, this delayed response may cause a buffer overrun if all the data packets were sent directly to the target. In order to prevent a possible buffer overrun, the data traffic modification device generates a series of hold acknowledgement primitives (starting at cycle **11** as depicted by the shaded cells) and transmits them to the

target. During cycles **9-12** the initiator continues to send data primitives. The traffic modification device buffers these primitives until the target device breaks the continued HOLD at cycles **19-21**. At cycles **21-23** the traffic modification device breaks the continued HOLD it has established with the initiator, and at cycle **23** the data traffic modification device begins to empty its FIFO by transmitting buffered data to the target. At cycle **27**, the FIFO has been emptied and the data traffic modification device sends a pair of ALIGN(0) primitives, for example, to keep the data line active until the "Data M" primitive sent by the initiator in cycle **26** can be sent to the target in cycle **29**.

FIG. **6** illustrates a table **600** that depicts an exemplary communications session among a SATA initiator (shown in a column **610**), a data traffic modification device's initiator port (shown in a column **620**), a data traffic modification device's target port (shown in a column **630**), and a SATA target (shown in a column **640**). It should be noted that this table does not represent any particular time scale, and is intended to be only a general depiction of one possible flow of communications. In this example, the initiator is sending data during cycles **1-3**, and then sends a HOLD-HOLD-CONT sequence during cycles **4-6**. The data traffic modification device responds by storing the current context that it is in (a continued R_IP), relaying the HOLD sequence to the target device during cycles **6-8** and by generating a series of HOLDA frames (depicted by shaded cells) as an acknowledgement to the initiator starting at cycle **8**. At cycle **12**, the initiator breaks the continued HOLD by sending a single HOLD primitive, after which the initiator resumes transmission of data frames during cycle **13**. The data traffic modification device responds by reestablishing the previously saved context by recalling that it was in a continued R_IP state and transmitting a R_IP-R_IP-CONT sequence to the initiator during cycles **17-19**.

FIG. **7** illustrates an exemplary block diagram depicting a process **700** for handling a pause request from a SATA target in a data traffic modification device, for example, the process illustrated by FIG. **5**. The process begins at step **701**, which could be entered automatically upon power-up, in response to a software request, in response to an electrical signal, or other methods for initiating a software process in a data traffic modification device or combinations thereof. At step **702**, a primitive is received from a target. If, at step **704**, the primitive received at step **702** is not a pause request, then control passes to step **708**.

At step **708** data is processed. For example, this may mean that the data received from the target may be processed or otherwise modified in a manner, for example, such as that described by blocks **212-214**, **220-228**, and **236** of FIG. **2**. At step **710**, processed data is sent to a host. Control then passes back to step **702**, to receive additional primitives from the target.

If, at step **704**, the primitive received at step **702** is a pause request primitive, then the process continues at step **706**. At step **706**, the pause request primitive is allowed to bypass data processing steps. At step **712** the unprocessed pause request primitive is sent to the host. At step **714**, the data traffic modification device begins to buffer data received from the host in a FIFO.

If, at step **716**, a acknowledge pause request primitive is received from the host, then control passes to step **720**. If, at step **716**, an acknowledge pause request primitive is not received from the host, then control passes to step **718**. During step **718**, the acknowledge pause request primitive is sent to the target.

If, at step **720**, the data traffic modification device does not receive a read in progress primitive from the target device, then control passes to step **718**. If at step **720** a read in progress primitive is received from the target, then the process continues at step **722**. During step **722**, data buffered in the FIFO (if any) during step **714** is sent to the target. At step **724**, a read in progress primitive is sent to the host. In some embodiments, this may signal the host that the target or the data traffic modification device is ready to accept data.

FIG. **8** is a block diagram of an exemplary process **800** for re-establishing a context in a data traffic modification device. The process begins at step **802**, which could be entered automatically upon power-up, in response to a software request, in response to an electrical signal, or other methods for initiating a software process in a data traffic modification device or combinations thereof. At step **804** a primitive is received from a target. If, at step **806**, the primitive is determined to be a continue request primitive, then control passes to step **808**. At step **808**, the data traffic modification device saves the context of the continue request primitive. For example, the continue request primitive may be part of a continued read in progress primitive combination of messages. In this case, the data traffic modification device would save information that would allow the data traffic modification device to recall the continued read in progress primitive state. After this information is saved, control passes to step **810**.

If, at step **806**, the primitive received from the target is not a continue request primitive, then control passes to step **810**. At step **810**, the data traffic modification device begins to buffer data from the target in a FIFO. At step **812**, the data traffic modification device may process of otherwise modify data from the host in a manner possibly such as that described by blocks **212-214**, **220-228**, and **236** of FIG. **2**. At step **814**, the processed data is sent to the host.

At step **816**, data is received from the host. If, at step **818**, the incoming data is a continued pause request primitive sequence, then control passes to step **820**. At step **820**, the continued pause request primitive sequence is sent to the target. At step **822** the data traffic modification device sets a holding state. In some embodiments, this may involve saving data, setting a register bit, or other types of computer memory, so the data traffic modification device can recall that the device is in this state. Control then passes to step **824**.

If, at step **818**, the incoming data is not a continued pause request primitive sequence, then control passes to step **824**. If, at step **824**, the data traffic modification device is not in a holding state, then the process continues at step **826**, otherwise the process continues at step **828**. At step **826**, the data traffic modification device sends a acknowledge pause request primitive to the initiator. The process then continues at step **832**, where any data that may have been buffered from the target is sent to the host.

At step **828**, the data traffic modification device recalls the state that was saved during step **808** and uses that state information to re-establish the continued state at step **830**. For example, if the saved state was a continued read in progress primitive state, the data traffic modification device may send a continued read in progress primitive sequence to the host. Control then passes to step **832** where any data that may have been buffered from the target is sent to the host. The process then returns to step **804** to receive additional primitives from the target.

FIGS. **9***a-c* illustrate a stream of data, and two exemplary data substitution processes being performed upon the data stream. FIG. **9***a* depicts a series of ten dwords in a section of a data buffer **900**, where each dword is numbered 0-9. In these examples, the dword **0** arrived in the buffer first, and each of the dwords arrived in sequence until dword **9** which arrived last. In FIG. **9***a*, the data traffic modification device has been

triggered to sample data from dword **4**. This trigger may be invoked by a predefined data pattern, an offset from the start of a data frame, after a timed offset, an external trigger stimulus, or any other method that may be used to trigger a data traffic modification device or combinations thereof. In this example, the data traffic modification device has been configured to sample the entire dword in cell **4**, but in other embodiments the data traffic modification device may be configured to sample any number of bits within a data frame.

FIG. **9***b* illustrates an example of a substitution process. In this example, the data traffic modification device has taken the data sampled from frame **4** and has used it to replace the data that was originally in frame **7**. In some embodiments, the data traffic modification device may perform this substitution upon any frame that may be encountered after the substitution data has been sampled. In some embodiments, a single trigger may invoke the sampling and substitution processes. In some embodiments, the sampling process and substitution process may be invoked by independent triggers. In some embodiments, one or more of the bits of sampled data may be used in the substitution process. In some embodiments, the sampled data may be modified by incrementing, decrementing, bit shifting, bit masking, by performing bitwise operations with the sampled and target data, or by other methods for modifying a collection of bits, in a data traffic modification device or by combinations thereof.

FIG. **9***c* illustrates an example of a substitution process that may be performed on buffered data. In this example, the data traffic modification device has taken the data sampled from dword **4** and has used it to replace the data originally found in dword **1**. Although dword I arrived in the buffer **900** prior to dword **4**, the data traffic modification device may still perform a substitution process upon dword I or any other dword that is held in the buffer **900**.

After a substitution process, such as those illustrated by FIGS. **9***a*-**9***c*, the data frame may no longer contain valid CRC data. The data traffic modification device may calculate valid CRC data based upon the contents of the frame, and replace the original CRC data with the valid, calculated CRC data.

FIGS. **10***a-d* illustrate an exemplary editor graphical user interface (GUI) **1000** for viewing and editing data modification scenarios. The editor GUI **1000** may be implemented as a software program running on a computer. In FIG. **10***a* the editor GUI **1000** includes an adaptive text interface **1010**, a scenario description **1020**, and a status indicator **1030**. In some embodiments the adaptive text interface **1010** may be capable of guiding the user through the scenario development process by displaying the scenario description as a collection of English (or other written language) phrases. In some embodiments, the adaptive text interface **1010** may provide a collection of editable fields or regions that the user may activate to full in information that defines a scenario. In some embodiments when the user invokes an editable region, the adaptive text interface **1010** may respond by presenting dialog boxes, wizards, entry blanks, dropdown list boxes, or other user input controls by which a user may enter data into a computer application. In the depicted example, the user has opened a new scenario template but has not yet entered any information into it.

A scenario that configures a data traffic modification device to do nothing may be considered to be a valid configuration. In some embodiments, the editor GUI **1000** may check the validity of scenarios in real-time as the user edits the configuration. In some embodiments, the editor GUI **1000** may check the validity of scenarios upon the request of the user, while saving a local copy of the scenario, while deploying a scenario to a data traffic modification device, or the like. Status indicator **1030** appears as a banner that is capable of displaying an indication of the validity status of the scenario. In some embodiments, this indication may be made using text, a graphical indication, animation, color coding, or other indications that may be used to convey a status or combinations thereof. In this example, the status indicator **1030** displays an indication of the validity status of the scenario description **1020**.

FIG. **10***b* illustrates the editor GUI **1000** and an exemplary adaptive text interface **1010**, including an incomplete scenario description **1050**. In this example, the user has added an event definition to the incomplete scenario description **1050**, but the user has not added a corresponding action definition. The editor GUI **1000** determines that the incomplete scenario definition **1050** is not a valid configuration for a data traffic modification device, and the status indicator **1030** is updated to reflect this validity status. In some embodiments, the status indicator may provide an interactive functionality that allows the user to jump to the source of the invalid state within the incomplete scenario definition **1050**. The editor GUI **1000** also includes an error location indicator **1040**, which may be used to point out the location of an error within the incomplete scenario description **1050**. In some embodiments, the error location indicator **1040** may appear as a graphical indicator, an animation, a color code, a text highlight, a font alteration, or a combination of these or other methods by which an erroneous line of a description may be indicated.

FIG. **10***c* illustrates an exemplary erroneous scenario definition **1060**. In this example, the user has added three sequences to the erroneous scenario definition **1060**. In this example, the user has edited more than the allowed maximum of two sequences. The editor GUI **1000** does not restrict the user from entering any invalid number of sequences to the erroneous scenario definition **1060**. The editor GUI **1000** displays indicator based on a determination that the erroneous scenario definition **106**C is invalid. The status indicator **1030** and error location indicator **1040** provide the user with a graphical indication of the erroneous status of the erroneous scenario definition **1060**.

FIG. **10***d* depicts an exemplary valid scenario definition **1070**. The editor GUI **1000** determines the valid state of the valid scenario definition **1070** as each edit is made, and status indicator **1030** is updated to reflect the valid status. Examples of editing scenario definitions are described in further detail in U.S. provisional patent application 60/779,084 entitled, "Scenario View Method and Apparatus," by Lee, D., et al., which was filed Mar. 3, 2006, and the contents of which are incorporated herein by reference.

In some embodiments the editor GUI **1000** may be capable of saving a scenario description as binary data locally, and/or to a data traffic modification device. In some embodiments, the editor GUI **1000** may be capable of saving the scenario definition in a human readable format (e.g., text, XML, CSV, HTML, tagged, and the like) either locally or to a data traffic modification device. In some embodiments, the editor GUI **1000** may be capable of retrieving scenario definitions from a data traffic modification device. In some embodiments, the editor GUI **1000** may be capable of synchronizing saved versions of scenario definitions between the computer running the editor GUI **1000** and the data traffic modification device. For example, a computer running the editor GUI **1000** may hold a version of a scenario that is at a different revision level than a scenario that is stored in a data traffic modification device. In some embodiments the editor GUI **1000** may provide the user with a method to synchronize the editor GUI **1000** and data traffic modification device to cause identical versions of a scenario to exist in both locations. In some

embodiments, the editor GUI **1000** may merge or otherwise reconcile the differences between two or more scenarios. In some embodiments, the editor GUI **1000** may be capable of querying the data modification device to determine the revision level of a scenario that may be saved on the data modification device. In some embodiments, the editor GUI **1000** may record information relating to one or more scenarios (e.g., scenario name, revision level, creation data, last modified date) on one or more data traffic modification devices. In some embodiments, scenario data may be saved in a manner that may allow the data to be correlated to manufacturing data (e.g., lot codes, serial numbers, and dates of manufacture). For example, a database may be queried in order to determine which version of a scenario was used to test a particular batch of manufactured disk drives. In some embodiments, scenario definitions may be deployed to a data traffic modification device through the use of a portable storage device. For example, a scenario definition may be saved to a floppy disk or a USB drive. When the user inserts the disk or drive into a data traffic modification device, the data traffic modification device may then provide a method for copying the scenario definitions on the disk or drive to the data traffic modification device.

In some embodiments, the data traffic modification device and the computer running the editor GUI **1000** may communicate through a common Ethernet network, and this communications link may allow the editor GUI **000** to save and/or retrieve scenario data to or from the data traffic modification device. In some embodiments, the data traffic modification device and the computer running the editor GUI **1000** may communicate through a universal serial bus (USB), IEEE488, IEEE1384, RS-232, RS-422, RS-488, or any other such serial or parallel communications bus or combinations thereof. In some embodiments, the editor GUI **1000** may save the binary or human readable scenario data in a compressed format. In some embodiments, the data traffic modification device may be used as a stand-alone instrument. For example, once a scenario definition has been saved to the data traffic modification device, the data traffic modification device may be disconnected from the computer running the editor GUI **1000**. Examples of using scenario definitions in a stand-alone data traffic modification device are described in further detail in U.S. provisional patent application 60/779,179 entitled, "Protocol Traffic Modification Method and Apparatus," by Fouxman, E., et al., which was filed Mar. 3, 2006, and the contents of which are incorporated herein by reference.

Although various embodiments have been described, further embodiments are possible. For example, some embodiments may be implemented with a stand-alone data traffic modification system, a waveform processing system, a digital storage oscilloscope, a protocol analyzer, or logic analyzer. Some implementations may include two or more channels to acquire multiple signals substantially simultaneously. Examples of various features and operational aspects of some implementations for performing traffic modification are described in further detail in U.S. provisional patent application Ser. No. 60/892,093 entitled, "Data Traffic Modifier Method and Apparatus" by Roy, A., et al., which was filed Feb. 28, 2007, and the contents of which are incorporated herein by reference.

Although some examples describe apparatus and methods with reference to data traffic modifiers, some features may apply to other implementations. For example, in one other embodiment, a variant of the described graphical user interface may be adapted for editing code for a protocol analyzer, oscilloscope triggering mechanism, logic analyzer, and/or other waveform processing systems.

In some embodiments, the data traffic modification device may receive updates, or be monitored and/or controlled from another (e.g., remote) computer with which the data traffic modification device can communicate over a communications link. Such a communications link may include a software control layer (SCL) running on the computer currently controlling the data traffic modification device. In some embodiments, the SCL may detect a failure to receive a complete version of expected data. The SCL may notify interested software layers that the request failed. Before sending a new request for the desired data to be transmitted, the SCL, based on the knowledge of previously failed receive attempts, may check whether it can read at least 1 byte of data. If there is no data in the receiving buffers, then the communication flow is considered restored, and the request to the data traffic modification device to transmit the desired data is sent.

If upon checking the buffers it is determined that the SCL can read at least one byte from the receiving buffers, the SCL will try to receive, read and discard any data that the device might be sending that is left over from the disconnected communication. When SCL determines that there is no longer any data in the receiving queue to read during some specified timeout (reached the state of "line silence") the communication flow is considered restored and the new request is sent to the data traffic modification device to transmit the desired data.

In some implementations, the physical connection may once again be lost during this process of "cleaning" the receiving queue before sending the new request. In such a case, even if the SCL considers the communication line to be clear, some data will remain in the device sending queue and will be sent to the SCL after the physical connection is recovered. In order to confirm proper operation, the SCL may check whether a new data response from the device has the same attributes as the request sent to the device from the SCL. If not, this received data is preferably discarded and the request may be reported as having failed. The communication flow recovery mechanism may remain active and it may try clear data from the receiving queue before sending a new request. Examples of restoring a software communications layer are described in further detail in U.S. provisional patent application 60/779,085 entitled, "Communication Flow Recovery Method and Apparatus," by Karpov, D., which was filed Mar. 3, 2006, and the contents of which are incorporated herein by reference.

In an illustrative example, the data traffic modification device may be used in a laboratory environment. For example, a user may edit a scenario with an editor GUI running on a first computer (e.g., the editor GUI **1000** of FIG. **10**). The GUI may provide an adaptive text interface to assist the user while editing the scenario. The editor GUI may also display a visible indication of the validity of the scenario substantially in real-time as the user enters each edit into the editor GUI **1000**. The scenario may be defined for use on a data traffic modification device. The user may disconnect the communications link to the data traffic modification device to operate the data traffic modification device as a stand-alone instrument. In some examples, the user may connect the data traffic modification device between a SATA host and a SATA target. In some embodiments, a trigger output of a data traffic modification device may also be connected to a trigger input of a protocol analyzer. Although a protocol analyzer is described in this example, the trigger output of the data traffic modification device may be connected to a variety of external devices which include, but are not limited to, oscilloscopes, power supplies, digital multi-meters, spectrum analyzers, waveform processing devices, automation systems, and the

like. In some examples, the user may configure the data traffic modification device to send a trigger output whenever it detects a continued pause request being sent across the SATA link. When the data traffic modification device detects this condition, it may respond by performing several actions. The data traffic modification device may stimulate the trigger output as defined by the user in the editor GUI. The data traffic modification device may save a context of the communications link prior to the arrival of the continued pause request, and buffer any data sent from the host or target prior to the host or target sending a hold acknowledgement message. The trigger output may cause the protocol analyzer to log all the data primitives that pass through the SATA link after the data traffic modification device detects the continued pause request. If the data traffic modification device receives a pause cancellation message, the data traffic modification device may respond by sending any buffered data and reestablishing the context of the SATA link prior to resuming the data transfer. The use may also edit the scenario with the editor GUI running on a second computer (e.g., the editor GUI **1000** of FIG. **10**) to load the scenario from the data traffic modification device to view or edit the scenario on the second computer.

In another illustrative example, a data traffic modification device may be used in, a manufacturing test environment. For example, a data traffic modification device may be connected in a SATA link between a test computer acting as a SATA host and a SATA disk drive in a disk drive testing system. A trigger input of the data traffic modification device may be connected to a programmable logic controller (PLC) that is controlling automated aspects of the manufacturing test process. The data traffic modification device may also connect to a development computer running an editor GUI (e.g., the editor GUI **1000**) across an Ethernet network to allow a test engineer to remotely develop and/or to deploy scenarios to the data traffic modification device. In some implementations, the test engineer may use the editor GUI to connect to one or more data modification devices and perform a synchronization process to distribute a common, synchronized version of a scenario definition to the manufacturing test environment. The test engineer may use the editor GUI to read and record information about the scenarios that have been deployed to the data traffic modification device, and that data may be relayed to a database that may be queried to determine which version of the scenario was used to test a disk drive associated with a particular serial number or lot code. A supervisory computer may use a software control layer (SCL) to connect to one or more data traffic modification devices in the manufacturing test environment. The PLC may connect the disk drive to the data traffic modification device, trigger the host computer to write data to the disk drive, and send a trigger to the data traffic modification device during the testing process. The supervisory computer may monitor the activity of the data traffic modification device and provide a link between the data traffic modification device and a manufacturing resource planning (MRP) system. If the communications link between the supervisory computer and data traffic modification device is interrupted, the SCL may attempt to recover the communications link in order to allow the MRP system to continue monitoring the data traffic modification device.

Various embodiments may include aspects of a computer. The essential elements of a computer are a processor for executing instructions and one or more memories for storing instructions and data. Suitable processors for the execution of a program of instructions include, by way of example, both general and special purpose microprocessors, which may include a single processor, or multiple processors in combination. The processor and the memory can be supplemented by, or incorporated in, ASICs (application-specific integrated circuits). Generally, a processor will receive instructions and data from a data store, such as a read-only memory (ROM), a random access memory (RAM), or both.

Generally, a computer will also include, or be operatively coupled to communicate with, one or more mass storage devices for storing data files. Storage devices suitable for tangibly embodying computer program instructions and data may include volatile and/or non-volatile memory (NVM), which may include, but is not limited to, semiconductor memory devices (e.g., RAM, EPROM, EEPROM, NAND flash, NOR flash, thumb drives), magnetic disks (e.g., hard disc drives), magneto-optical and/or optical media (e.g., CD, DVD).

In some implementations, one or more user-interface features may be custom configured to perform specific functions. Various embodiments may be implemented in a computer system that includes a graphical user interface and/or an Internet browser. To provide for interaction with a user, some implementations may be implemented on a computer having a display device, such as a CRT (cathode ray tube) or LCD (liquid crystal display) monitor for displaying information to the user, a keyboard, and a pointing device, such as a mouse, stylus, or a trackball by which the user can provide input to the computer.

In various embodiments, systems such as the data traffic modification device **105** may communicate using suitable communication methods, equipment, and techniques. For example, the data traffic modification device **105** may communicate with a portable computer, network server, or other device using point-to-point communication in which a message is transported directly from the source to the receiver over a dedicated physical link (e.g., fiber optic link, point-to-point wiring, and daisy-chain). Other embodiments may transport messages by broadcasting to all or substantially all devices that are coupled together by a communication network, for example, by using omni-directional radio frequency (RF) signals, while still other embodiments may transport messages characterized by high directivity, such as RF signals transmitted using directional (i.e., narrow beam) antennas or infrared signals that may optionally be used with focusing optics. Still other embodiments are possible using appropriate interfaces and protocols such as, by way of example and not intended to be limiting, RS-232, RS-422, RS-485, 802.11a/b/g, Wi-Fi, Ethernet, IrDA, FDDI (fiber distributed data interface), token-ring networks, or multiplexing techniques based on frequency, time, or code division. Some implementations may optionally incorporate features such as error checking and correction (ECC) for data integrity, or security measures, such as encryption (e.g., WEP) and password protection.

In some embodiments, each memory may be programmed with the same information and be initialized with substantially identical information stored in non-volatile memory. In other embodiments, one or more devices may be custom configured to perform specific functions.

A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope. For example, advantageous results may be achieved if the steps of the disclosed techniques were performed in a different sequence, if components in the disclosed systems were combined in a different manner, or if the components were replaced or supplemented by other components. The functions and processes (including algorithms) may be performed in hardware, software, or a combination thereof, and some implementations may be performed on modules or hardware

not identical to those described. Accordingly, other implementations are within the scope of the following claims.

What is claimed is:

1. A method of processing a waveform that comprises signals compliant with a version of a Serial Advanced Technology Attachment (SATA) protocol, the method comprising:
- receiving and sampling a bi-directional data stream from a source device over a first SATA-compliant data link;
- selectively modifying the received data stream by monitoring the data stream and modifying at least one bit in the data stream in response to detecting a trigger condition, wherein at least one bit to be modified is received in a buffer before receiving data that fulfills the trigger condition;
- sending the selectively modified data stream to a target device over a second SATA-compliant data link;
- receiving a SATA-compliant hold request signal comprising a SATA HOLD primitive from the target device;
- generating a SATA-compliant hold acknowledge signal comprising a SATA HOLDA primitive to send to the target device in response to the received hold request signal;
- sending the received hold request signal to the source device;
- buffering the data stream after receiving the hold request signal and at least until the source device interrupts the data stream in response to the hold request signal;
- receiving a resume signal from the target device to resume transmission of the data stream; and
- sending the buffered data to the target device in response to receiving the resume signal.

2. The method of claim 1, further comprising restoring a context of the data stream in response to receiving the resume signal and before resuming transmission of the data stream.

3. The method of claim 1, wherein the trigger condition comprises a user-specified data value in the data stream.

4. The method of claim 1, further comprising sending the hold acknowledge signal to the target device within up to 20 double words after receiving the hold request signal.

5. The method of claim 1, further comprising monitoring signals from the target device to detect the hold request signal.

6. The method of claim 1, wherein sending the received hold request signal to the source device comprises propagating the received hold request signal through the buffer.

7. The method of claim 6, wherein the buffer comprises a first-in, first-out buffer.

8. The method of claim 1, wherein the signal from the target device to resume transmission of the data stream comprises a SATA-compliant primitive to cancel a SATA-compliant continuation primitive in effect.

9. The method of claim 1, wherein the target device comprises a data storage device.

10. The method of claim 9, wherein the data storage device comprises a rotating data storage medium.

11. The method of claim 1, further comprising sampling the data stream with a protocol analyzer.

12. The method of claim 1, wherein the step of selectively modifying the data stream comprises selectively modifying data in data traffic in more than one direction.

13. A method of processing a waveform that comprises signals compliant with a version of a Serial Advanced Technology Attachment (SATA) protocol, the method comprising:
- receiving and sampling a bi-directional data stream at an input module of a data traffic modification device, the data traffic modification device being configured to buffer the received data stream in a buffer module, to selectively modify data in the received data stream in response to a trigger signal indicating the occurrence of a predefined condition, wherein at least one bit to be modified is received in the buffer before receiving data that causes the signal indicating the occurrence of the predefined condition, and to transmit the selectively modified data stream from an output module, wherein the input module is connectable to a source device and the output module is connectable to a target device;
- monitoring data in the received data stream;
- detecting in the monitored data a SATA-compliant signal comprising a HOLD primitive to request a pause in the data stream;
- generating a SATA-compliant signal comprising a HOLDA primitive to acknowledge the pause request signal;
- pausing the transmission of the selectively modified data stream in response to the pause request signal;
- identifying a state instruction most recently received by the data traffic modification device before receiving the pause request signal;
- storing the identified state instruction; and
- before resuming transmission of the data stream, sending the stored state instruction to the source device to reestablish the stored state of the data stream.

14. The method of claim 13, wherein the step of sending the stored state instruction to the source device comprises consecutively sending the stored state instruction at least twice to reestablish the stored state.

15. The method of claim 13, wherein the version of the SATA protocol is compatible with SATA 2.0.

16. The method of claim 13, wherein the data stream comprises signals compliant with a version of a serial attached SCSI (small computer serial interface) protocol.

17. The method of claim 13, wherein the target device comprises one or more electronic data storage devices.

18. The method of claim 13, wherein the input module is connectable to a source device through a data bus expander device.

19. The method of claim 13, wherein the output module is connectable to a target device through a data bus expander device.

20. The method of claim 13 further comprises sending a pause acknowledgement signal to the source device within a predefined response specification after receiving the pause request signal.

21. The method of claim 20, wherein the predefined response specification corresponds to receiving up to a threshold quantity of data in the data stream after receiving the pause request signal.

22. The method of claim 13, wherein the threshold quantity of data is 20 double words.

23. A method comprising:
- selectively modifying data traffic being conveyed in a bidirectional data transfer between a source device and a target device by monitoring and sampling the data traffic and modifying at least one bit in the data traffic in response to a detected trigger condition, at least one bit to be modified is received in a buffer before receiving data that fulfills the trigger condition, the data traffic in the data transfer comprising state information for the target device;
- storing the state information during the data transfer;
- receiving a Serial Advanced Technology Attachment (SATA) compliant HOLD primitive hold request from the source device to pause the data transfer;

generating a SATA compliant HOLDA primitive hold acknowledgement in response to the received host request;

pausing the data transfer in response to the hold request;

receiving a signal from the source device to resume the data transfer;

generating signals to send to the source device, the generated signals corresponding to the stored state information in effect at the time of pausing the data transfer; and,

resuming the data transfer after sending the generated signals.

24. The method of claim **23**, wherein the generated signals comprise at least two sequential SATA-compliant primitive values corresponding to the stored state information.

25. The method of claim **23**, wherein receiving the request from the source device to pause the data transfer comprises monitoring the data traffic.

26. The method of claim **25**, wherein receiving the request from the source device to pause the data transfer further comprises detecting in the monitored data a SATA-compliant signal to request a pause in the data stream.

27. The method of claim **23**, wherein selectively modifying the data traffic comprises introducing a data error.

28. The method of claim **27**, wherein selectively modifying the data traffic further comprises updating an error detection value in the data traffic such that the updated error detection value corresponds to the selectively modified data with the introduced data error.

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